Final report for grant 053063 entitled Delayed Optoelectronic and delayed Incoherent Feedback Lasers

Experiments done by David Sukow at Washington and Lee University explored a new form of optical feedback where the light polarization is rotated before reinjecting into the laser. The main observed phenomena is the emergence of square-wave oscillations for the two laser-polarization states oscillating in antiphase. This problem became the source of a fruitful collaboration between the three groups (Thomas Erneux in Brussels, Tom Gavrielides in Albuquerque, and David Sukow in Lexington).

It was soon realized that this problem offers new opportunities both for the understanding of the effects of optical feedback on semiconductor lasers but also as high frequency optical sources. Numerical simulations were first done at Kirtland, then in Brussels, and they motivated an analytical investigation of the laser delay differential equations. As a result, two conferences papers have been presented in 2006 [6, 7] and a joint publication in Optics Letters has appeared [4]. The work was later publicized by the SPIE Newroom in 2007 [9]

Experiments indicate that other forms of square-wave or pulsating oscillations are possible. Preliminary numerical and analytical work has emphasized the role of key parameters, namely, the different losses between the two laser polarization states and the delay of the optical feedback. More recently, New experiments using Vertical Surface Emitting Laser (VCSELs) have been undertaken at Lexington. VCSELs are know to exhibit two nearly degenerate polarization states and have been studied in detail by several laboratories in the world. The experiments however indicate that the square-wave oscillations are not so easily observed as for the case of edge-emitting lasers. These experiments raised a series of questions. The fact that square-wave oscillations are observed in bursts suggest that some parameters (possibly detuning) are changing during the experimental recording. From the modeling point of view, we might need to consider a more accurate model that the one used for Edge Emitting lasers (specifically, the so called spin-flip model). These issues are currently investigated.

The dynamical effects of a delayed orthogonal feedback possibly leading to novel appli-

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14. ABSTRACT

This report results from a contract tasking Universite Libre de Bruxelles as follows: Lasers are ubiquitous today, mostly in the form of semiconductor lasers (SLs), which are characterized by smallness in size, weight, cost of production, and power requirements. Optical networks depend on SLs for generation, amplification, and distribution of the light that transmits voice, video, and data. However, an unfortunate property of these devices is their high susceptibility to unavoidable optical feedback, such as reflection from any optical element of the system surrounding the laser. Even tiny amounts of optical feedback (less than 0.01%) can cause the laser to enter a state of erratic pulsating instabilities and irregular chaotic transitions. Systematic experimental studies started recently. Fourier spectra measurements showed the gradual emergence of new frequencies as the feedback rate is progressively increased. But time series are still delicate to obtain because of the extremely small time scale of the intensity pulsations. Most of our understanding of these instabilities came from numerical simulations of simple model DDEs where the delay is the round-trip time of the light from the laser to the mirror and back to the laser. We propose to investigate the bifurcation possibilities of these lasers by combined analytical and numerical techniques. The goal is to find simple guidelines on the properties of the pulsating solutions and/or frequencies. The properties of several types of feedback will be compared. Finally, we shall investigate the case of two mutually injected lasers because of a series of experiments studied at Kirtland AFB.

15. SUBJECT TERMS
EOARD, Laser physics, semiconductor lasers, Laser dynamics

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cations has become a new topic of research as evidenced by two recent publications [1, 2]

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